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The Effects of Different Stretch Protocols on Vertical Jump, Speed, and Hamstring Flexibility in Elite Female Camogie Players

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Literature Review

Introduction

There is very little data available on the training and conditioning of camogie (Ladies Hurling) players. To ensure higher standards of training and match performance for camogie players it is important that more data can be collected on the effects of different training and stretching protocols specific to that group and their effects on performance. There are many different types of stretching with the main three being static stretching (SS), proprioceptive neuromuscular facilitation (PNF) and dynamic stretching (DS). Each of these stretching methods will have its own section that will look at how each relates with increasing flexibility and how it effects the main physical components of camogie; jumping and sprinting. Drawing on data collected from other sporting populations as a starting point will allow for quicker assembly on appropriate and effective training methods for camogie players.

Stretching was once never considered a part of training and then it progressed to being an integral part of every warm-up and workout. The type, amount, and timing of stretching was then investigated in its contribution to performance and flexibility. This has led to some authorities recommending a move away from stretching or at least an adjustment to its prescription. This review will look at different types of stretching and how they effect performance and flexibiliy. These performance tests will look at attributes that are needed in the game of camogie such as sprinting, jumping and peak force among others.

Hurling is an outdoor team game of ancient Gaelic and Irish origin, administered by the Gaelic Athletic Association (GAA). The game is believed to have been played for over 3,000 years, and claims to be the world's fastest field team game. It shares a number of features with Gaelic Football, such as the field and goals, number of players, and much terminology. There is a similar game for women called Camogie. Founded in 1904, Camogie, an independent voluntary organisation, is the most popular female team sport in Ireland while making a significant contribution to the Irish culture, as part of the family of Gaelic games.

There is little or no data specific to camogie. To determine the main physical attributes for camogie there are many studies done on hurling, which shares the majority of the same rules as Camogie, and gaelic football which shares many of the same rules and physical needs as camogie and hurling.

Fitzpatrick (2006), in a study on gaelic games, indicated that it takes 4-5 seconds for an athlete to reach their maximum running speed. Therefore their “playing speed” is of a greater concern than their maximum running speed. In hurling, the player is continually being challenged to accelerate and decelerate from differing positions. Players are not required to run at the same pace for any length of time. Of all the accelerations in a game, 70% are under 10 steps. This is important as many of the studies that will be quoted on stretching look at sprinting ability over short distances (10-40 metres).

Data from Young (2007) points to the sports of hurling and camogie being inherently high intensity, multi-sprint, contact field games that rely on a variety of contrasting performance related attributes that include speed, power, agility, reaction time, coordination, strength, aerobic and anaerobic endurance. Flexibility is a crucial part of performance as it affects stride length. This is of profound importance as sprint speed is equal to stride length times frequency (O'Neill, 2009). This adds to the rationale that flexibility is needed and that stretching is an important component of performance and is why it is measured

The results of a study by Watson (1996) suggest that the incidence of injuries in hurling is high and may be attributed to poor conditioning, poor protection, and lack of enforcement of the rules. Of the above mentioned reasons for injury, poor conditioning is an area that can be controlled by the individual and the team to try and reduce the incidences of muscle strain.

Murphy, Gissane, and Blake (2012) showed that the injury incidence rate during match-play was 19 times higher than for training. Muscle strain accounted for 42.2% of the total. Of the injuries sustained, 71% were to the lower limb with hamstring strain (16.5%) predominating. The data for this study was collected by questionnaire and it was outside the scope of the study to monitor how warm-ups were performed but from the data it appears that more attention must be paid to how warm-ups are performed for training versus matches. It is critical that care is taken to use the best type of warm-up systems for camogie as this will lead to fewer injuries as shown by the data above.

The above data shows that sprinting and jumping are critical components to performing camogie at a high level. It also indicates that flexibility, especially hamstring flexibility, is crucial to performance and injury prevention. Therefore, anything that hinders or increases these physical attributes, in the case of stretching, is vital to know.

Static Stretching

The area of stretching, especially static stretching (SS), is an area that has a very divided opinion on what is best and safe for the general population and the sports performance athlete to do. This section will review the history and current literature on SS and how it can be related to the performance tests for camogie. Whether SS is best before or after training is another area that is currently being questioned. Given that pre-exercise routines commonly incorporate several modalities that include cardiovascular work, progressive muscular contractions and muscle stretching, the specific element or combination of elements responsible for improving performance and reducing injury risk is impossible to deduce.

In the American College of Sports Medicine (ACSM) first guidelines from 1978 there were no recommendations for stretching. These were some of the first fitness and health guidelines ever released. Later guidelines from the ACSM (1998) state that stretching needs to be part of a well planned warm-up session to increase range of motion (ROM), enhance performance in the proceeding activity and prevent musculoskeletal injuries. The type of stretching used, when it is used and what type of activity it precedes or follows has been a major debate in the last 20 years.

According to Baechle and Earle (2008) the previous benefits; injury prevention, muscle soreness reduction, of SS were being questioned. Baechle and Earle recommend only performing SS for sports like gymnastics that require an increased range of motion. The American College of Sports Medicine's guidelines (2010) suggested the removal of SS as part of a warm-up routine and that if strength and power are major components of the performance then only include cardiovascular work.

In a study on elite level youth soccer players Jordan, Korgaokar, Farley and Caputo (2012), showed there was no significant difference between static stretching (SS) and PNF in Balsom agility tests ($p = .66$) and there was no significant difference between the control and SS group ($p = .15$) and the control and the PNF treatment group ($p = .58$). The Balsom Agility Test or Balsom Run (Balsom, 1994) is a test of agility designed for the soccer player, in which the participants are required to make several changes of directions and two turns. This is a test of speed, body control and the ability to change direction (agility). It very closely mimics the demands of a game of soccer. A 3-minute general warm-up and a 2-minute sports specific warm-up with a soccer ball were performed. Immediately after completion of the control run, either static or PNF stretching was performed on the hamstrings, quadriceps, gastrocnemius, and solei. The treatment was reversed for the following trial for a counterbalanced experiment. SS was held for 30s at a point of mild discomfort. Each stretch was completed twice on each leg for each muscle group. The PNF stretch consisted of ten seconds of a passive stretch at mild discomfort, then followed by an isometric contraction of six seconds and finished with a passive stretch of 30 seconds. This was done twice on each leg for each muscle group. This study showed that neither form of stretching had an effect, either positive or negative, on a sports specific performance test. The 30 seconds that finished the PNF stretch could be deemed as a static stretch and could therefore negate the positive effects attained by the PNF.

La Torre, et al. (2010) studied the effects of pre-exercise stretching on muscle performance at higher angles similar to those needed in sprinting and jumping in seventeen male participants (age 23 ± 3 years) that were currently active in recreational or competitive sports. The squat jump was tested at various knee angles with main outcome variables being vertical peak force, velocity, acceleration, and maximal power. There was a significant decrease in all power variables tested (velocity, acceleration and maximal power) with lower knee angles (50º and 70º) with a negligible effect on performance in static jump at higher knee angles (90º and 110º). The vertical jump dropped by 0.6cm at 90º knee angle but actually increased by 0.2cm at 110º knee angle. The tests were performed after an 8 minute warm-up on a treadmill and either a 10 minute SS session consisting of stretches of 30 seconds with 30 seconds rest performed four times on each muscle (quadriceps and ankle plantar flexors) at the point of discomfort or the control of a 10-minute rest. Participants were given 40 seconds rest between static jumps for the first three sets and 90 seconds for the last two sets. This could have impacted negatively on the force production as it is stated by King (1999) that from five up to ten minutes is needed between maximal power efforts.

In a systematic review by Kay and Blazevich (2012), of 4,559 possible articles only 106 passed the criteria set (included studies were assessed for methodological quality using the PEDro scale - the PEDro scale is a valid measure of the methodological quality of clinical trials [de Morton, 2009]), they concluded that there is clear confirmation indicating that static stretches that are held for 30 seconds or less have no detrimental effect, with conclusive evidence that stretch durations of 30–45s also imparted no significant effect. Of the stretch durations examined 30 seconds had a lot less data to extrapolate from (speed and power had four studies, strength had three studies). Does this mean that the sample sizes were too small to see a decrease or can conclusive decisions be reached with such a small sample size? Of these studies only 14% showed a decrease in performance and this decrease was only 1.1% ± 1.8%.

However, 61% of the included studies showed a reduction (-4.2% ± 5.0) occurred with stretches greater than 60s in duration in all measures (performance in strength, power, and speed-dependent tasks, across contraction modes and muscle groups in the lower limb). There were a total of 73 studies that looked at stretch durations of greater than 60s. The drop for stretches held for greater than 120s was 7% ± 5.7%. Their recommendation is that static stretching can be included as part of a warm-up routine so long that the stretch duration does not exceed 60 seconds. They also state that “no systematic review has focused specifically on the acute effects of SS on maximal muscle efforts.” even though many papers conclude that SS has a detrimental effect on performance, specifically, power output.

Of the 106 articles included, 55% reported a significant reduction of performance in tasks that were strength, power or speed dependent. Task performances were shown to not be affected in 69% of the cases. The authors attribute this to improper reporting or incorrect reporting of the findings of the studies. Where appropriate control or reliability was demonstrated only two studies reported a significant reduction in performance. This is in comparison to the same tasks in 15 other studies reporting no difference in performance. The drop off in performance seems to have a greater effect on certain muscles with the knee flexors (82%) more regularly influenced by SS compared with the knee extensors (64%). This could mean adjusting not only the length of the static stretch but also which muscles need to receive static stretching as part of the warm-up.

A meta-analysis by Simic, Sarabon, and Markovic (2013) on a total of 104 studies published between 1966 and 2010 that met the inclusion criteria showed that the duration of stretch can effect the outcome of the test. These effects were not related to participants' age, gender, or fitness level. Simic, Sarabon and Markovic list the review by Kay and Blazevich (2012) but state "none of those studies actually used an appropriate statistical tool for combining and analyzing individual study findings in a quantitative manner."

The meta-analysis showed a likely negative effect on maximal muscle strength with the same acute negative on athletes and non-athletes. There was a significantly larger ($p = 0.012$) pooled negative acute effect of SS observed for isometric vs dynamic strength tests. If the activity or sport being played has more isometric than dynamic movements involved this means, according to these results, that SS could have a greater negative effect. In pooled estimates, it was shown that the duration of the stretch also changed the outcome of the result relating to maximal muscle strength. Stretches lasting less than 45 seconds averaged a -3.2% effect, stretches that were between 45 and 90 seconds showed an average decrease of -5.6% and stretches over 90 seconds showed the greatest average negative effect of -6.1%.

The effect of SS on muscle power was unclear. After analysis between athletes and non-athletes there was a similar unclear effect. Although limited by the number of studies, subgroup analysis related to stretch duration showed a trend ($p = .10$) toward reduction of the negative acute effect of SS on muscle power with shorter stretch duration. Pooled estimates for the acute effect of SS per muscle group on muscle power lasting less than 45s were 0.4%, for 46–90s it was -1.7%, and greater than 90s was -3.3%. For the explosive muscular performance tests, when expressed in percentages, the respective pooled estimate was -2.0%, indicating a very likely negative acute effect of SS on explosive muscular performance. In particular, pooled estimates for the acute effect of SS lasting <45, 46–90, and >90s per muscle group on explosive performance were -0.8%, -2.5%, and -4.5%, respectively. The conclusion from this study was that only using static stretching as an activity during a warm-up should be avoided.

Even with regards to muscle endurance, SS seems to have a negative effect (Nelson, Kokkonen & Arnall, 2005). Knee flexion muscle strength endurance was measured on 11 male and 11 female college students by exercise performed at 60 and 40% of body weight following either a no-stretching or stretching regimen. The stretching protocol involved performing the sit-and-reach test for four 30 second holds, stopping at the point where the stretch is felt, with 15 seconds of rest in between stretches. Stretches for the calf were also performed. Participants relaxed for 10 minutes before performing the endurance tests. When exercise was performed at 60% of body weight, stretching significantly ($p < 0.05$) reduced muscle strength endurance by 24%, and at 40% of body weight, it was reduced by 9%. The authors of the study recommended that heavy SS exercises of a muscle group be avoided prior to any performances requiring maximal muscle strength endurance. Studies previously quoted had said that stretches lasting less than 45s seemed to have no negligible effect on muscle performance so maybe strength endurance is negatively effected at a much lower dose of SS.

From all the above results it is shown that, at best, static stretching doesn't effect performance and at worst it has a detrimental effect on performance. This has been shown in both genders, across a variety of sports and at all levels of competition. Judging by these results it would be best to avoid SS as part of warm-up before any sporting performance unless high levels of flexibility are necessary for performance. The general consensus that it is not beneficial is a reason why it is not part of the following study.

PNF

Proprioceptive neuromuscular facilitation (PNF) is a form of stretching that can be performed several ways but always involves some form of muscle contraction. It has become popular in the past couple of decades as an alternative to SS as part of a warm-up. This section will review the methods and current literature on PNF and how it can be related to flexibility and the performance tests that relate to camogie.

Nelson and Cornelius (1991) showed that the effects of maximum voluntary isometric contraction (MVIC) for 3, 6 and 10 seconds in PNF training on range of motion in the shoulder joint were not different, although all the MVIC durations increased the range of motion significantly.

Sanavi, Zafari and Firouzi (2013) showed that PNF stretching increased hamstring flexibility but there were no significant differences between durations of 5, 10 and15s (22.45%, 23.85% & 24.5% respectively). It was also shown that combining different PNF stretching (5, 10 & 15s) with a strength training program including progressive overload had a greater effect on increasing hamstring one repetition maximum than performing strength training alone (25%, 30%, and 25% respectively). It must be noted that these results were achieved in a non-athletic population.

Khodayaria and Dehghani (2012) showed, with contract relax (CR) PNF stretching (Chaitow, 2001), no significant difference between different intensity of PNF stretching (20, 40, 60 and 80 percentages) on improving hamstring flexibility. The study was performed on 75 non athletic healthy college students aged between 18 and 26. The PNF method used was a maximal isometric contraction with the hamstring muscles for six seconds, followed by ten seconds of relaxation. The tester extended the participants' leg further while they relaxed but not to a point of discomfort. This was repeated an additional two times for a total of three repetitions. The only difference observed belonged to the control group in comparison with other experimental groups. The control group performed no stretching intervention.

Feland and Marin (2004) also showed that contract relax PNF stretching "using submaximal contractions is just as beneficial at improving hamstring flexibility as maximal contractions, and may reduce the risk of injury associated with PNF stretching." For the study 72 healthy college age men, who had qualified as having "tight" hamstrings as determined by the inability to reach 70° hip flexion in a straight leg raise, were randomly assigned to one of three test groups: 1, 20% of MVIC; 2, 60% of MVIC; 3, 100% MVIC.

The results attained by using a 20% or 60% MVIC were comparable with the effectiveness of a 100% MVIC during CR PNF hamstring stretching. All groups using the intervention improved flexibility more than the control group that performed no stretching work. The maximum contraction group averaged a slightly greater increase but in the authors opinion "is not clinically significant." By using reduced contraction strength the results are similar to 100% but the chance of injury is greatly reduced.

In a well quoted study by Marek et al (2005) ten female (age, 23 ± 3 years) and nine male (age, 21 ± 3 years) apparently healthy and recreationally active volunteers performed static and PNF stretching and calculated its effect on different range of motions and performance tests. Four repetitions of each stretching exercise (static or PNF) were held for 30 seconds at a point of discomfort but not pain, as acknowledged by the participants. The PNF stretches used a modified technique in which the participants maintained maximal isometric tension of the leg extensors against a manual resistance (applied by the investigator) for five seconds, followed by a 30-second passive stretch. Between repetitions, the leg was returned to a neutral position for a 20-second rest period. The 30 second hold was performed after the contraction. Does this 30s hold reduce the effect of the PNF and as a result of the length of the hold does the stretch become more a static stretch than a PNF stretch?

Both SS and PNF stretching caused similar deficits in strength, power output, and muscle activation at both slow ($60°·s^{-1}$) and fast ($300°·s^{-1}$) velocities. The active range of motion (AROM) and the passive range of motion (PROM) increased as a result of the SS and PNF stretching with the SS showing a slightly greater increase than the PNF stretching. Results indicated that peak torque (PT) and mean power output (MP) decreased from pre-stretching to post-stretching at 60 and 300°/s in response to both the static and PNF stretching. In addition, PT decreased, whereas MP increased from 60 to 300°/s, which was consistent with the traditional force-velocity and power-velocity relationships during maximal concentric isokinetic muscle actions.

Their findings indicated that EMG amplitude for the vastus lateralis and rectus femoris muscles decreased from pre-stretching to post-stretching at 60 and 300°/s in response to both the static and PNF stretching. This could indicate that stretching-induced decreases in performance may not be velocity specific. It must be noted that these results are obtained from an isokinetic leg extension. Further investigation is needed to see if these results would repeat themselves on a more traditional full body performance test such as a vertical jump.

Carvalho et al. (2012) observed that a dynamic stretching intervention appears to be more suitable for use as part of a warm-up in young tennis athletes with a minimum of two years of participation in the sport. They assessed the effects of four different groups: Control Condition (CC)— 5-minutes of passive rest; Passive Stretching Condition (PSC)— 5-minutes of passive SS; Active Stretching Condition (ASC)— 5-minutes of active SS; and Dynamic Stretching Condition (DC)—5 minutes of dynamic stretching on the effects of performance tests. Their performance tests consisted of three squat jumps (SJs) and three countermovement jumps (CMJs), which were measured electronically. Each session consisted of a general and specific warm-up, with 5-minutes of running followed by ten jumps, accompanied by one of the subsequent conditions

For the SJ, 1-way repeated measures revealed significant decreases for ASC and PSC conditions when compared with CC. For CMJs, there were no significant decreases ($p = .05$) when all stretching conditions were compared with the CC. Significant increases in SJ performance were observed when comparing the DC with PSC. Significant increases in CMJ performance were observed when comparing the conditions ASC and DC with PSC. Stretching exercises were designed for the hamstrings, quadriceps, and triceps surae muscles. They consisted of three sets of exercises with 15 seconds maintained in the stretch position. For the dynamic stretching protocol, the same procedures were followed, but instead of holding the stretching positions for 15 seconds, the participants had to bob in 1:1-second cycles for 30 seconds trying to reach a greater stretch in each repetition

The authors of the study concluded that “results provide evidence that dynamic stretching appears to cause no significant acute effect for this population when used in conjunction with a specific warm-up. Practitioners and coaches should avoid SS when designing warm- up routines” The results of this study also demonstrated no increase or decreases in the CMJ performance after any of the stretching conditions when compared with the CC.

From the above it was shown that PNF can increase range of movement (ROM) with no differences in contraction times used and no difference in the intensity of the contraction. PNF was shown to have a positive effect on increasing hamstring flexibility with some results showing better increases in ROM compared to other forms of stretching. There is not as much information on PNF related to performance in general or to the specific performance tests related to camogie so further study is needed.

Dynamic Stretching

Dynamic stretching (DS) involves a series of movements that are more sport specific than traditional static stretching. They are designed to prepare the muscles for performance and are performed in a safe and controlled fashion. In a lot of cases the terms DS and ballistic stretching (BS) are used interchangeably but in some instances BS is performed more explosively. This section will review the methods and current literature on DS and how it can be related to flexibility and the performance tests that relate to camogie.

Fletcher and Jones (2004) showed that active DS was more effective as part of a warm-up for improving performance in 20 metre sprint times in amateur rugby players than passive SS, active SS and static dynamic stretching. The main finding from this study was a significantly faster sprint time when active DS was incorporated into a warm-up, with significantly slower sprint times observed for participants employing either static active or passive stretching regimes.

The active dynamic stretch group carried out a series of lower body dynamic stretches (controlled movement through the active range of motion for each joint) at a jogging pace. Exercises were designed to stretch the gluteals, hamstrings, quadriceps, adductors, hip flexors, gluteals, hamstrings, gastrocnemii and solei. Participants performed 20 repetitions on each leg independently, with a walk-back recovery. It also must be noted that “a small minority had a decrease in performance through the dynamic intervention and had an increase in performance after the static stretch”.

Unick, Kieffer, Cheesman and Feeney (2005) in a study on the effects of static and ballistic stretching on vertical jump in trained women showed there was no significant decrease in vertical jump performance for either ballistic or SS. All participants were recruited from a highly competitive National Collegiate Athletics Association Division III women's basketball team. The participants performed stretches for the hamstrings, calves and quadriceps. Each stretch was held for 15 seconds at the point just before discomfort for 3 repetitions. For the ballistic stretching protocol the participants performed the same stretches as above but once the stretched position was reached they performed one bob (or bounce) per second. The results of this study suggest that the acute effects of stretching may not adversely affect power performance in trained women.

Faigenbaum, McFarland, Schwerdtman, Ratamess, Kang and Hoffman (2006) showed that warm-up protocols that included dynamic exercise resulted in superior performance on the vertical jump and long jump as compared with a warm-up protocol that included SS. There was no control protocol for this study so there is no baseline score to judge the effects of the protocols they used on a standard performance. The participants were high school female athletes, primarily basketball players and track athletes. The dynamic warm-up was nine exercises starting with moderate intensity (speed skips) progressing to more high intensity exercises (sprints and high knee skips).

Bradley, Olsen and Portas (2007) showed that vertical jump height in eighteen male university students decreased after static and PNF stretching (4.0% and 5.1%, $p < 0.05$) and after ballistic stretching there was a smaller decrease (2.7%, $p > 0.05$). However, jumping performance had returned to the same scores as measured before any intervention 15 minutes after all stretching conditions. The ballistic stretching consisted of four repetitions on five exercises with a 5 second hold and then 25 bobs/pulses in the stretched position. The muscles stretched were the gastrocnemius, adductors, supine hamstring, prone quadriceps, and kneeling quadriceps.

This study seems to suggest that if any stretching intervention is needed before an athletic event that includes some form of vertical jump then at least 15 minutes should have elapsed from completion of stretching to the commencement of the event. This will negate any of the negative effects of decreased performance from the stretch intervention. There was no ROM test performed so it couldn't be evaluated if there was an increase in ROM from the interventions and if they would have remained or returned to normal after the various rest intervals (1, 5,15, 30, 45 and 60 minutes).

Dalrymple, Davis, Dwyer, and Moir (2010) showed that in twelve female collegiate volleyball players there were no significant differences between static stretching, DS, and no stretching conditions for any of the counter movement jumps performed ($p > 0.05$). For the dynamic protocol 2 sets of calf raise, slow butt kicks, leg swings to opposite hand and knee tucks were performed for 18 metres after a 5 minute jog and 2 minute walk to warm-up.

One thing that needs to be considered from this is that there were individual responses to the different testing protocols. Seven participants produced greater increases in peak jump height ranging from 3-8% after the DS, whereas only one participant produced a greater peak jump height after the static SS protocol when compared with the dynamic stretching protocol. Four participants demonstrated no difference between the stretching conditions. When considering which warm-up and stretching protocol to use it has to be noted that there can be different responses from individuals, both positive and negative, to different approaches.

According to Behm and Chaouachi (2011) in a comprehensive review, with regard to DS, “the literature tends to indicate that shorter durations (1-60s) of DS do not adversely affect performance, and longer duration (greater than 60s) of dynamic stretches may facilitate performances”. This review showed that due to the close comparability of movements it is more desirable to perform DS as part of a warm-up, as opposed to SS, for physical activity. Improvements were reported in shuttle run time, medicine ball throw distance, jump height, and five step jump distance.

It was shown that performing dynamic stretching at different cadences has an effect on the performance outcome. It was shown that 100 beats/min resulted in significantly greater countermovement jump and drop jump heights than DS activities using 50 beats/min but there was still significant improvement with the lower cadence. Another element the authors examined is the force of the DS. They said there were inconsistencies in the reporting of the stretch intensities in the dynamic stretch studies which make it difficult to compare between studies. Part of the conclusion from this review is that an optimal warm-up should be composed of a aerobic activity of sub-maximal intensity followed by DS performed at a large amplitude and then finished with sport specific dynamic activities. It was also noted that “dynamic stretching provides similar acute increases in static flexibility as static stretching”.

Fattahi-Bafghi and Amiri-Khorasani (2012) showed that there was a significant difference (0.12 ± 4.45 m) between a warm-up followed by DS or dynamic exercise in the vertical jump performance in nineteen professional soccer players. There was a significant difference after DS compared to the SS protocol. Dynamic exercise did not produce a higher record to complete the vertical jump test compared to DS. There were no significant differences between dynamic exercise and static stretching on power, but dynamic exercise showed better record than SS.

The authors concluded that “According to their training and exercise level, it seems that dynamic exercise was strange and not familiar motions for them; therefore they were not able to respond with better records in power and agility. Results suggest that DS during warm-ups, as compared to static stretching, is probably most effective technique as preparation for the required power in soccer”

From the above information dynamic stretching has been shown to increase flexibility in some cases and if performed at a certain cadence (100bpm) can improve performance in 20 metre sprint tests. It was also shown to be very effective in certain individuals and not in others under exactly the same test conditions. It therefore requires more study before further assertions can be made.

Conclusion

Static stretching, at once a critical part of the warm-up, is now considered only needed in sports that require extreme ranges of motion such as gymnastics and should not be included for any field sports in the warm-up.

Proprioceptive neuromuscular facilitation (PNF) has been consistently shown to increase range of motion of the treated muscle. There is not as much information on PNF related to performance in general or to the specific performance tests related to camogie so further study is needed.

Dynamic stretching (DS) has been shown to increase flexibility as much as other modes of stretching such as static and PNF. In many studies it has also been shown to improve performance compared to control groups and also to other forms of stretching.

If performing any type of stretching as part of a warm-up for a field sport the evidence points to DS as being the best option as it increase flexibility and increases performance in tests such as vertical jump and 20 metre sprints.

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Research Article

Abstract

Background:

At this time there is very little data available on the training and conditioning of Camogie (Ladies Hurling) players. A warm-up is an important part of preparation for a Camogie match (Young, 2007). Stretching is typically part of the warm-up, however, debate exists as to the most suitable type of stretching to perform.

Aims:

The purpose of this study was to examine the effects of dynamic stretching (DS) and proprioceptive neuromuscular facilitation (PNF) stretching on physical performance markers in elite Camogie players.

Methods:

Participants attended three separate testing dates (approximately one week between sessions). Each session lasted approximately an hour. Participants completed tests on vertical jump, 20 metre sprint and sit-and-reach after a sports specific warm-up followed by one of the interventions. Week 1 testing was the control with weeks 2 and 3 being DS and PNF respectively.

Results:

There was a significant difference (p = .019) between the dynamic group (18.09 inches) and the PNF group (17.56 inches) in vertical jump heights. There was a significant difference (p = .006) between the control group (3.39s) and the PNF group (3.55s) on the 20 metre sprint test. There was a significant difference (p = .00) between the PNF group (3.55s) and dynamic group (3.39s) on the 20

metre sprint test. There was a significant difference ($p < .001$) between the control group (26.25 inches) and the PNF group (27.58 inches) on the sit-and-reach test. There was a significant difference ($p = .043$) between the control group (26.25 inches) and the dynamic group (27.08 inches) on the sit-and-reach test. There were no significant differences on any other tests.

Conclusion:

This data shows that stretching can affect performance markers in elite Camogie players. Flexibility was improved by both interventions. PNF was detrimental to performance compared to the control in 20 metre sprint tests. PNF also caused a drop in performance compared to DS on the vertical jump. If the goal is increased flexibility then either intervention can be beneficial but neither intervention showed improved performances and in some cases performance was worse.

Introduction

The game of Camogie (Ladies Hurling) is an inherently high intensity, multi-sprint, contact field sport that relies on a variety of different performance-related, or fitness-related, components or attributes. Examples of such attributes include speed, power, agility, reaction time, coordination, strength, aerobic and anaerobic endurance (O'Neill, 2009). In a study on male hurlers it was shown that 72% of game time is spent walking or stationary with only 3% sprinting and 2% at maximum speed levels (Young, 2007). Even though the percentages of the sprint and max sprint levels are low they can be the difference between winning and losing a game and therefore sprinting performance is critical to the game of Camogie.

At this time there is very little data available on the training and conditioning of Camogie players. There are several studies on injury type and rates from Camogie with the most recent being Quinn and Bradley (2012). These studies have focused more on hand and facial injuries that occurred as a result of being struck by the hurley (the implement used to strike the ball or "sliotar"). To ensure higher standards of training and match performance for Camogie players it is important that more data can be collected on the effects of different training and stretching protocols specific to that group. Drawing on data collected from other sporting populations as a starting point will allow for quicker assembly on appropriate information and effective training methods for Camogie players.

One key question is what effects will different stretching procedures during pre-Camogie game warm-ups (proprioceptive neuromuscular facilitation {PNF} or dynamic stretching) have on vertical jump, 20 metre sprint time, and hamstring flexibility when compared to a pre-game warm-up with no stretching included? The hypothesis is that PNF stretching and/or dynamic stretching will increase performance in the specific fitness components mentioned above when compared to no stretching procedure included in a pre-game warm-up.

The aims and objectives of the current study were to investigate whether there are any significant differences between warm-ups that include either of two different types of stretching protocols (PNF and Dynamic) and a warm-up without any stretching protocol in elite female Camogie players.

Flexibility training is a component of fitness and it is sometimes considered important in the daily routine of many athletes. There is an ongoing debate of what type of flexibility training is best suited for different sports people. But most importantly the biggest question to be answered is, does conducting stretching exercises before competition improve or hinder athletic performance? Many believe that flexibility training can play a major role in the prevention of injury (Smith, 1996) while, on the other hand, studies have indicated that static stretching as part of a warm-up may decrease short sprint performance in athletes (Fletcher & Jones, 2004). It is studies such as these that have led other sport physiologists to investigate the effects of other types of stretching techniques on athletic performance.

Generally it has been accepted that increasing the flexibility of a muscle-tendon unit improves performance (Woolstenhulme, Griffiths, Woolstenhulme, E. & Pacrell, 2006) but in some cases evidence has suggested that stretching has no beneficial effect (Bazett-Jones, Gibson & McBride, 2008). It has also been shown that too much dynamic flexibility work can hinder performance in 20metre sprint times if performed for too many repetitions (Turki, et al, 2012). It is for these reasons this study investigated the effects of different stretching techniques such PNF and Dynamic on specific fitness components in elite female Camogie players.

Static stretching, which is a major component of many team's warm-up protocols, was not inlcuded in this study as there is over whelming evidence that it has no beneficial effect on performance. A meta-analysis by Simic, Sarabon, and Markovic (2013) on a total of 104 studies published between 1966 and 2010 that met the inclusion criteria showed that the duration of stretch can affect the outcome of the test with stretches less than 45 seconds having the least negative effect. These effects were not related to the athlete's age, gender, or fitness level. The meta-analysis showed a likely negative effect on maximal muscle strength with the same acute negative on athletes and non-athletes.

PNF was originally developed to rehabilitate patients with paralysis. Sports therapists then began using certain techniques of PNF with healthy athletes to increase their range of motion to improve performance (McAtee, 1993). The PNF stretches are performed statically with very little movement. On the other hand dynamic stretching which attempts to put specific muscles through a full range of motion while moving has also been used by coaches and players to improve performance (Pearson, 2004). Why might one protocol be better than the other? More importantly does stretching improve performance?

The study focused on specific fitness components (Ostojic, Mazic & Dikic, 2006) namely anaerobic power, speed and hamstring flexibility. The players were monitored conducting tests that focus on short and intense protocols in order to simulate typical movements performed by Camogie players during competition. These tests will include 20 metre sprint, sit-and-reach test and vertical jump.

The purpose of this research is to establish if there are significant effect differences between the three methods of stretching protocols conducted (PNF, dynamic or no stretching (control). The variables measured were the mean difference between the baseline test performed and post stretching protocol test performed (for each different protocol) for each of the three fitness tests. Before analysis, the data was tested for normal distribution, that variance before and after is similar, and the observations are independent.

Methods

The sample size was seventeen participants (a Camogie team is made up of fifteen players with substitutes).The team selected was the Dublin Ladies Camogie team. These players are considered elite as they have competed at the highest level of competition in their sport, the All-Ireland Senior Championship. All participants were free of injury and illness.

Participants were asked to maintain their normal activity over the whole study duration. Participants were not allowed to consume coffee, tea, or other stimulants two hours before the beginning of the experimental procedure. Participants were preliminarily informed about the possible risks of the experimental procedures. A written informed consent to participate in the study was obtained from all the enrolled participants before the beginning of the study, and the experimental protocol was preliminarily approved by the Faculty of Life Sciences, University of Chester, Research Ethics Committee.

All participants attended three separate testing dates (approximately one week between sessions). Each session lasted approximately an hour. The first session acted as the control. The participants performed a ten minute pulse raiser that consisted of Camogie drills such as shooting, passing and carrying drills (O'Connor, 2011) and were then tested for each of the fitness components (vertical jump, hamstring flexibility and speed) with the exclusion of any stretching protocol.

The protocol for the 20 metre sprint test has been previously published (Delextrat and Chen, 2008). Briefly, the participants were allowed 3 trials for the 20 metre sprint, starting in a stationary position, with the fastest performance recorded. The times were recorded by the timing gates (Brower Timing system) placed at the start and finish lines. It was noted that the participants all held the hand that usually holds their hurley almost stationary when performing the 20 metre sprint test. This would effect their maximum speed as arm movement can affect top speed.

The protocol for the vertical jump test was as detailed by Delextrat and Chen, (2008). The test is performed by starting in a standing position with feet hip distance apart. From this stationary position each participant takes one step backward with one foot, and then brings both feet square before jumping as high as possible. Arm swing is allowed during the test. The participants perform three jumps with at least 30-seconds recovery, and the best result was recorded (Read & Cisar, 2001). The jump height is usually recorded as a distance score. The Takei Physical Fitness Test Jump-MD (jump mat) was used to measure all jump heights. This is an electronic device and it measured the height jump to the nearest one tenth of an inch. Centimeters is the preferred method of measurement but the device only gave readouts in inches.

The protocol for the sit-and-reach test has been previously published (Liemohn, Sharpe, & Wasserman, 1994). The “Sit and Reach Test” measures the flexibility of the lower back and hamstring muscles using a sit-and-reach box. This test involves sitting on the floor with legs out straight ahead. Feet (shoes off) are placed with the soles flat against the box, shoulder-width apart. Both knees are held flat against the floor by the tester. With hands on top of each other and palms facing down, the participant reaches forward along the measuring line as far as possible. After three practice reaches, the fourth reach is held for at least two seconds while the distance is recorded. The score is recorded to the nearest half inch. Centimeters is the preferred method of measurement but the device only gave readouts in inches.

The first session acted as the control. The participants performed a ten minute pulse raiser that consisted of Camogie drills such as shooting, passing and carrying drills (O'Connor, 2011) and were then tested for each of the fitness components (vertical jump, hamstring flexibility and speed) with the exclusion of any stretching protocol.

The second and third session followed the same protocol as the first session with either the DS or PNF performed after the ten minute pulse raiser. The performance tests were then performed with the same protocols as the first session.

The Dynamic Stretches were adapted from Pearson (2004). They included each of the following that were performed forwards and backwards for 20 metres: high knee-lift skip, hamstring buttock flick, walking hamstring, forward lunge, Russian walk, side lunge, advanced core lunge, walking on balls of feet, wall drill-linear leg forward and back ten each leg, wall drill-leg out and across the body ten each leg.

PNF stretching was performed using the contract-relax-antaganoist-contract (CRAC) method according to published guidelines (McAtee, 1993). This PNF method requires the tester to bring the participants' muscle to its lengthened pain free range. The participant contracts the muscle against the tester causing an isometric contraction. The participant builds from 50% to 100% contraction. After every contraction the participant inhales deeply and as they relax they increase the length of the stretched muscle. This is repeated 3 times. PNF was performed on the following muscles: hamstrings, quadriceps, gastrocnemius, short adductors.

Of the seventeen participants that started the study, only twelve completed the full three testing days. Only data from the twelve participants that completed all the testing days was included in the analysis.

Results

On the vertical jump test there was no significant difference ($p = .42$) between the control condition (17.67 inches) and the PNF condition (17.56 inches). There was no significant difference ($p = .07$) between the control condition (17.67 inches) and the DS condition (18.09 inches). There was a significant difference ($p = 0.019$) between the DS condition (18.09 inches) and the PNF condition (17.56 inches).

On the 20 metre sprint test there was a significant difference ($p = .006$) between the control condition (3.39s) and the PNF condition (3.55s). There was no significant difference ($p = .94$) between the control condition (3.39s) and the DS condition (3.39s). There was a significant difference ($p = .00$) between the PNF condition (3.55s) and DS condition (3.39s).

On the sit-and-reach test there was a significant difference ($p = > .001$) between the control condition (26.25 inches) and the PNF condition (27.58 inches). There was a significant difference ($p = .043$) between the control condition (26.25 inches) and the DS condition (27.08 inches). There was no significant difference ($p = .19$) between the PNF (27.58 inches) condition and DS condition (27.08 inches).

Discussion

The purpose of this study was to establish if there was a significant effect difference between the three methods of stretching protocols conducted {proprioceptive neuromuscular facilitation (PNF), dynamic stretching (DS) or no stretching (control)}. The hypothesis that PNF stretching and/or dynamic stretching would increase performance in the specific fitness components (vertical jump, 20 metre sprint and sit-and-reach) when compared to no stretching procedure included in a pre-game warm-up was not supported by the data.

This study showed that no stretching as compared to the other tested protocols (Dynamic and PNF) had the least detrimental effect to sports performance in elite Camogie players. This is an important finding as the majority of team sports include an element of stretching as part of their warm-up routine. These warm-up routines have included static stretching (SS) for many years but due to studies and meta-analysis showing that SS can impair performance, teams and athletes are now looking for alternatives to SS.

The American College of Sports Medicine's guidelines (2010) suggested the removal of SS as part of a warm-up routine and that if strength and power are major components of the performance then only include cardiovascular work. A meta-analysis by Simic, Sarabon, and Markovic (2013) showed a likely negative effect on maximal muscle strength with the same acute negative on athletes and non-athletes alike with the application of SS.

There are many forms of stretching but two of the most popular alternatives to SS include PNF and DS. These forms of stretching are being included more and more frequently in warm-up protocols and the body of evidence for both is growing. It is critical to test these protocols on the specific population that they are intended for so that direct references can be drawn from the results.

The above study showed an increase in range of motion for the sit-and-reach test from PNF and this has been shown by nearly every study on PNF (Nelson & Cornelius, 1991, Feland & Marin, 2004, Khodayaria & Dehghani, 2012). The above study showed a decrease in performance from performing PNF as part of the warm-up. This corresponds to previous work by Marek et al, (2004) that showed that PNF causes deficits in strength, power output, and muscle activation. Contrary to the findings of the above study, PNF has been shown to increase strength in one repetition maximum tests (Sanavi, Zafari & Firouzi, 2013).

The above study showed that performing DS as part of a warm-up doesn't show a significant difference in vertical jump performance ($p = 0.07$) when comparing DS to no stretching. This has also been shown by Bradley, Olsen and Portas (2007) in eighteen male university students and Dalrymple, Davis, Dwyer, and Moir (2010) in twelve female collegiate volleyball players.

In the 20 metre sprint test there was a significant difference ($p = .006$) between the control condition and the PNF condition. This equated to the control condition being 0.16 seconds faster over the 20 metre distance. This doesn't seem like much but it could be an extra metre over such a short time. Such small differences can really add up if this is for every player on the field of play. There was also a significant difference (p= 0.00) between the PNF group (3.55s) and the DS group (3.39s). The DS group was 0.16 seconds faster than the PNF group.

If the goal of the warm-up is to increase flexibility then PNF and DS were both shown by the above study to increase flexibility greater than the control (no stretching intervention). However, if the goal of the warm-up is to increase flexibility but have little or no detrimental effect on 20 metre sprints and vertical jump then, according to the above study, DS can be incorporated into the warm-up. There was no significant difference (p = 0.07 & p = 0.94 respectively) between the control group and DS group on vertical jump and 20 metre sprint test. The difference between the control group and DS group on the 20 metre sprint was that the DS group was 0.002 of a second slower. The difference between the control group and the DS group on vertical jump was that the DS group was 0.42 of an inch higher than the control group. So even though it didn’t show up as significant it was still almost half an inch more. On the sit-and-reach test there was a significant difference (p = 0.043) between the control and the DS group with the DS group getting an extra 3/4 of inch more range of movement. In two of the three tests the DS group scored better. So if Camogie players are looking for the slightest edge, and the data was examined more closely, then doing DS as part of a warm-up for Camogie players can have beneficial effects with only a slight decrease in sprint times.

It must be noted that improved performances in 20 metre sprint tests have been shown by Fletcher and Jones (2004). This study showed a significantly faster sprint time in amateur male rugby players doing DS in their warm-up as compared to SS. DS has also been shown to have a superior performance increase on vertical jump and long jump when it is included as part of the warm-up (Faigenbaum, McFarland, Schwerdtman, Ratamess, Kang & Hoffman, 2006)

One thing that needs to be considered from the above study is that there were individual responses to the different testing protocols. Some individuals showed an improvement with some interventions that overall showed a decrease in performance. This has been further corroborated by Dalrymple, Davis, Dwyer, and Moir (2010) whom showed that there were within group differences in response to different modes of stretching. Certain individuals improved their performance on the same protocol that caused a decrease in performance in other individuals. Further research into the specifics on the mechanisms of why this presents itself in studies on stretching could help individualize stretching protocols meaning that every single player gets the stretching protocol that helps them increase their own performance.

The above study could have benefitted from having a greater number of participants to draw upon. Initial testing started out with seventeen participants but only twelve participants completed the three separate testing days.

This was the teams and participants first exposure to these stretching methods. The team could be tested on several occasion with the same stretching interventions to see if the drop in performance was due to being exposed to DS or PNF for the first time or if the interventions would continue to show a decrease in performance regardless of the amount of exposures. Further research would be needed to test this hypothesis. Further research would also be needed to see if the results would be reproducible in a team to be considered a lesser standard and a team considered to be at a higher standard as the team tested would have been ranked in the top eight teams in the country. The above study could also have benefitted from being randomised control as every player performed the stretching interventions in exactly the same order which could have led to a learning effect.

Conclusion

The recommendation from the data obtained from this study would suggest as part of a correct warm-up for elite Camogie players they would only need to perform their sports specific warm-up drills to perform at their best at 20 metre sprints and vertical jump. It must also be noted from the data that if the goal of the warm-up is to achieve increased range of movement without a decrease in performance than dynamic stretching can be considered a viable option.

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Young, D. (2007). Presentation. Time and Motion Analysis of Inter-County Hurling. (MSc Thesis).

Appendices

Appendix 1 - Letter from Dublin Camogie Manager

THE CAMOGIE ASSOCIATION

MAKE-A-WISH. Ireland

8th March 2013

To Whom It May Concern:

RE; John Connor

On behalf of the Dublin Camogie County Board (Coiste Chontae Camogaíochta Baile Átha Cliath) I fully endorse the use of our training facility at Trinity Grounds, Santry and that John can use our senior players as participants in order to complete the sample tests required for his thesis. Dublin Camogie County Board is happy to provide access to our facility and players on the dates that John needs.

Please feel free to contact me if you have any further queries on the matter at

amogie

Coiste Chontae Camogaíochta Baile Átha Cliath
Runaí – Mona Uí Shúilleabháin
4 Orlagh Court
Knocklyon
Dublin 16

Appendix 2 -Participant Information Sheet

Participant information sheet

Effects of different stretch protocols on vertical jump, speed, hamstring flexibility and agility in elite female camogie players

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take your time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

Warming-up and stretching prior to games and practice has been viewed as being very important with regards to physical pre-game preparation and possible injury prevention.

With so many different opinions and an abundance of accessible data it is difficult to know if the pre-game stretching regimen a team is performing actually does prepare those players to perform at their physical best and furthermore, highlight if any of the regimens are obsolete.

The aim of this study is to investigate the effects (acute) of two different pre-game stretching regimens (Dynamic and PNF) and one control period with no stretching intervention (camogie drills only) with regards to vertical jump, sprint time, hamstring flexibility and agility in female camogie players.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

If you decide to take part, you will be given this information sheet to keep and asked to sign the consent form. This will give your consent for a researcher from the Department of Clinical Sciences & Nutrition at the University of Chester to test you with relation to specific components of fitness at baseline and retest the same variables at the end of all three sessions to investigate if there are any significant differences as a result of the stretching interventions. Participants are required to abstain from alcohol on the day of, and during, each of the three sessions.

What are the possible disadvantages and risks of taking part?
The only risks that are possible would be if the stretching procedures are not performed correctly there is a very small risk of a slight muscle pull. But all the procedures will be explained, demonstrated and monitored.

What are the possible benefits of taking part?
A benefit of taking part in this study is that you as players will have the chance to see just how specific warm-ups affect different components of fitness such as sprinting, jumping, agility and flexibility. As players, the results will indicate which stretching protocols work best to achieve maximum physical performance during pre-competition.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, University of Chester, Parkgate Road, Chester, CH1 4BJ, 00 44 1244 513055.

Will my taking part in the study be kept confidential?
All information, which is collected, about you during the course of the research will be kept strictly confidential so that only the researchers carrying out the research and research supervisor will have access to such information.

What will happen to the results of the research study?
The results will be written up for an MSc Dissertation for the University of Chester. Later they may be published. These results will provide another insight into the on going debate on the benefits of different stretching regimens for athletes. No participants will be identified in any reports.

Who is organising and funding the research?
The research does not require any funding. The Department of Clinical Sciences & Nutrition at the University of Chester will be involved in organising and carrying out the study.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

John Connor

Email:

Thank you for your interest in this research

Appendix 3 - Consent Form

Title of Project: Effects of different stretch protocols on vertical jump, speed, hamstring flexibility and agility in elite female camogie players

Name of Researcher: John Connor

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected.

3. I agree to take part in the above study.

Name of Participant　　Date　　Signature

Researcher　　Date　　Signature

1 for participant; 1 for researcher

Appendix 4 - Risk Assessment

Potential Hazard	Control Measures to be Adopted
Inappropriate clothing worn by participants i.e loose t-shirts or unsuitable footwear.	All participants will be contacted by researcher individually via e-mail or letter with regards to times, dates, clothing, footwear etc.
Slippery surface.	Each day the floor will be checked and cleaned by the researcher to ensure the floor is safe enough to be used each day.
Inappropriate use of fitness equipment during fitness tests.	All participants will be shown the correct safe way to perform each test by the researcher. The participants will all be closely monitored during every stage of the fitness tests.

Appendix 5 - Pulse Raiser

Pulse raiser consisting of camogie drills only.

Exercise: 1

Groups: 3, 4 or 5 players
Sliotars: 1 per group
Cones: 6
Skills: Controlling, Striking, Lifting, Soloing, Handpassing, Catching, Batting, Dribbling, Kicking
Level of Effort: 2.5/5
Level of Complexity: 1.5/5

Set-up:

Use four of the cones to form a rectangle that is about 15 metres wide and long enough to accommodate the required number of groups. Place the last two cones about 5 metres further out to give the option of a 20 metre distance.

Players break up into groups of three (or five) and have the groups split with two (or three) people at cone A and one (or two) players at cone B 15 metres away. The first player at A has a ball.

Description:

Player 1 starts with the ball in his hand and runs towards Player 2 at B. Half way across he rolls the ball along the ground in front of player 2 and then follows the ball to cone B and takes his position there.

Player 2 controls the ball, runs towards Player 3 at cone A, rolls the ball along the ground in front of player 3 and this follows the ball to cone A can takes his position there. Player 3 controls the ball and continues the cycle.

The ball should be rolled gently as players are just starting off and are just looking to get the eye in and the heart rate up slightly. Continue for about one minute and then work through some of the following variations changing again after about a minute or so.

Exercise: 2

This is a variation of exercise 1 with the following changes:

Throw the ball head high with a firm, flat throw for the next player to catch to warm up the catching hand.

Exercise: 3

Groups: of 3 players
Sliotars: 2
Cones: 3
Skills: Striking, Controlling, Catching
Level of Effort: 3/5
Level of Complexity: 1.5/5

Set-up:

Arrange cones in a 50m line as shown below. Players on either end have a ball.

Description:

Player 1 strikes the ball to 2 who controls the ball and strikes the ball back to 1. Immediately player 3 strikes the ball into 2 who controls and strikes it back.

Repeat as described. Give each player 2 to 2½ minutes in the middle.

Exercise: 4

This is a variation of exercise 3 with the following changes:

To encourage players to move on to the ball set up four cones for the middle player as below with 10m metres between the cones. Players move on to the ball and strike the ball from the outside the line of the cones.

O'Connor, G. (2011). *Give Us A Game: The Games Book For Hurling & Gaelic Football.*
Dublin: Genprint Dublin

Appendix 6 - Health Screening Form

Health Screen Questionnaire

Effects of different stretch protocols on vertical jump, speed and hamstring flexibility in elite female camogie players

Researcher*:* John Connor

Name:________________________________ Test date:_______________

Address:____

Contact number:___________________________ Date of birth:__________

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. YES/NO Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor?

2. YES/NO Do you feel pain in the chest when you perform physical activity?

3. YES/NO In the past month, have you had chest pain when you were not performing physical activity?

4. YES/NO Do you lose your balance because of dizziness *or* do you ever lose consciousness?

5. YES/NO Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity?

6. YES/NO Have you injured your hip, knee or ankle joint in the last six months?

7. YES/NO Do you know of any other reason why you should not participate in physical activity?

Thank you for taking your time to fill in this form. If you have answered 'yes' to any of the above questions, unfortunately you will not be able to participate in this study.

Appendix 7 - 20 Metre Sprint Test

20-m Sprint

Sprint or speed tests can be performed over varying distances, depending on the factors being tested and the relevance to the sport.

- Purpose: The aim of this test is to determine acceleration, and also a reliable indicator of speed, agility and quickness.
- Equipment required: Brower Timing System (Timing Gates)
- Description / procedure: The subjects are allowed 2 trials for the 20-m sprint, starting in a stationary position, with the fastest performance recorded. The sprint is performed on the basketball court, and the times will be recorded by the timing gates (Brower Timing system) placed at the start and finish lines. The 20-m sprint test has demonstrated high levels of reliability in physically active men (correlation coefficient of 0.91 between test and retest) and does not need an practice session beforehand (Moir, Button, Glaister & Stone, 2004).
- Results: Two trials are allowed, and the best time is recorded to the nearest 2 decimal places. The timing starts from when the timing system is triggered, and finishes when the chest crosses the finish line and the finishing timing gate is triggered.

Delextrat & Chen (2008). Physiological testing of basketball players: toward a standard evaluation of anaerobic fitness. *Journal of Strength & Conditioning*. 22(4): 1066-72

Appendix 8 - Sit & Reach Test

Sit and Reach Test

This test measures the flexibility of the lower back and hamstring muscles.

- **Equipment required:** sit and reach box (or alternatively a ruler can be used, and held between the feet)
- **Description / procedure:** This test involves sitting on the floor with legs out straight ahead. Feet (shoes off) are placed with the soles flat against the box, shoulder-width apart. Both knees are held flat against the floor by the tester. With hands on top of each other and palms facing down, the subject reaches forward along the measuring line as far as possible. After three practice reaches, the fourth reach is held for at least two seconds while the distance is recorded. Make sure there is no jerky movements, and that the fingertips remain level and the legs flat.
- **Scoring:** The score is recorded to the nearest centimetre

Liemohn, Sharpe, & Wasserman, (1994) Criterion related validity of the sit-and reach test. *Journal of Strength & Conditioning Research*. 8(2): 91-94

Appendix 9 - Vetical Jump Test

Vertical Jump Test

This procedure describes the method used for directly measuring the height jumped. There are also timing systems that measure the time of the jump and from that calculate the vertical jump height.

i. **Equipment:** Takei Physical Fitness Test Jump-MD (jump matt)
ii. **Description / procedure:** The test is performed by starting in a standing position with both feet together. From this stationary position each subject takes 1 step backward with 1 foot, and then bring both feet together before jumping as high as possible. Arm swing is allowed during the test. The subjects perform 3 jumps with at least 30-seconds recovery, and the best result was recorded (Read & Cisar, 2001).
iii. **Scoring:** The jump height is usually recorded as a distance score.

Delextrat & Chen (2008). Physiological testing of basketball players: toward a standard evaluation of anaerobic fitness. *Journal of Strength & Conditioning Research.* 22(4): 1066-72.

Appendix 10 - PNF Protocol

University of Chester

PNF Stretches (CRAC technique)

1) Supine Hamstring (assisted) X 3 for each leg
2) Prone Quadriceps (assisted) X 3 for each leg
3) Gastroscnemius (assisted) X 3 for each leg
4) Short adductors (unassisted) X 3

McAtee, E.R. (1993). Facilitated Stretching: PNF Stretching Made Easy. United States of America.
Human Kinetics, pp. 13-50.

Supine Hamstring

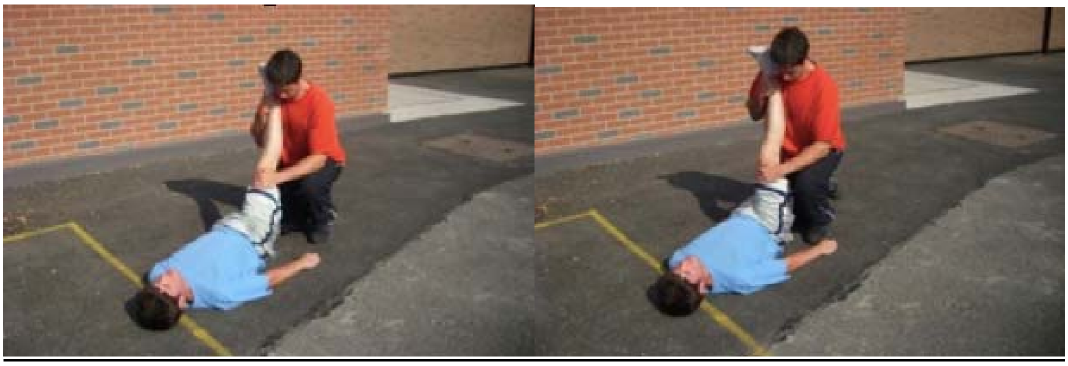


Figure 1A Figure 1B

1. The stretcher is supine
2. The stretcher lifts his leg, with the knee straight, as high as possible. This lengthens the hamstring to its pain-free range.
3. Offer resistance to the isometric contraction of the hamstring (no movement), at the same time making sure that the stretcher keeps his hips on the ground (Figure 1a).
4. The stretcher pushes his heel toward the ground, isometrically contracting the hamstring for 6 seconds. The stretcher begins slowly and builds from 50% to 100% of maximum contraction, breathing throughout.
5. The stretcher relaxes, breathes deeply, then contracts his hip flexors to the lift the leg higher, with knee straight (figure 1b). This deepens the hamstring stretch. Never push to deepen the stretch. As the stretcher lifts his leg higher, hold the knee straight and move in to offer resistance again.
6. Repeat 3 times
7. The stretcher must keep his hips flat on the ground. If necessary, stabilize them with your hand.

Prone Quadricep


Figure 2a   Figure 2b

1. The stretcher lies prone, with knee flexed as far as possible (Figure 2a). This lengthens the quads to their end of range.

2. Offer resistance to the isometric contraction (no movement) of the quads by placing your hand against stretchers shin.

3. The stretcher tries to straighten his leg, isometrically contracting the quads. for 6 seconds. The stretcher begins slowly and builds from 50% to 100% of maximum contraction, breathing throughout.

4. The stretcher relaxes, breathes deeply, then contracts the hamstring, deepening the quad stretch (figure 2b).

5. Repeat 3 times

6. This is one of the few PNF stretches where you may push gently to assist the stretch. After the second round of stretching, you may gently push the heel toward the buttock to help overcome the fleshly resistance of the calf and hamstring.

Gastrocnemius

Figure 3a

Figure 3b

1. The stretcher lies supine and places hands on either side on the ground to keep from sliding during the isometric phase.

2. The stretcher dorsiflexes his foot as far as possible. This lengthens the gastrocnemius/soleus to its end of range.

3. Offer resistance to the isometric contraction of the gastrocnemius/soleus by placing both hands around the foot and using your body weight to prevent plantar flexion (Figure 3a).

4. The stretcher tries to point his foot (plantarflex), isometrically contracting the gastrocnemius/soleus, for 6 seconds. The stretcher begins slowly and builds from 50% to 100% of maximum contraction, breathing throughout.

5. The stretcher relaxes, breathes deeply, then contracts the tibialis anterior, deepening the gastrocnemius/soleus stretch (figure 3b).

6. Repeat 3 times

Adductors

Figure 4a

1. Stretcher sits upright on the ground with feet touching.

2. Offer resistance to the isometric contraction by using the elbows pressed against the inside of each knee (figure 4a).

3. The stretcher presses his elbows outward but at the same time pulls his knees inwards for 6 seconds. The stretcher begins slowly and builds from 50% to 100% of maximum contraction, breathing throughout.

4. The stretcher relaxes, breathes deeply and again uses his elbows to stretch the adductors, this deepens the stretch.

5. Repeat 3 times.

Appendix 11 - Dynamic Stretching Protocol

Dynamic stretching protocol

Dynamic Stretches

1) High Knee-lift skip 1 x 20m forwards and 1 x 20m backwards
2) Hamstring buttock flick 1 x 20m forwards and backwards
3) Walking Hamstring 1 x 20m left shoulder leading, 1 x 20m right shoulder leading
4) Forward lunge 1 x 20m forwards, 1 x 20m backwards
5) Russian walk 1 x 20m left shoulder leading, 1 x 20m right shoulder leading
6) Side lunge 1 x 20m left shoulder leading, 1 x 20m right shoulder leading
7) Advanced core lunge 1 x 20 forwards, 1 x 20m backwards
8) Walking on balls 1 x 20m forwards, 1 x 20m backwards
9) Wall drill-linear leg forward and back 10 X each leg
10) Wall drill-leg out and across the body 10 X each leg

Pearson, A. (2004). Dynamic Flexibility: Warming up on the move. Great Britain. *A&C Black*
Publishers Ltd, pp. 10-48.

High Knee-Lift Skips

Aim

To improve buttock flexibility and hip mobility. To increase ROM over a period of time. To increase body temperature.

Description

Cover 20 metres in a high skipping motion. Return to the start by repeating the drill backwards.

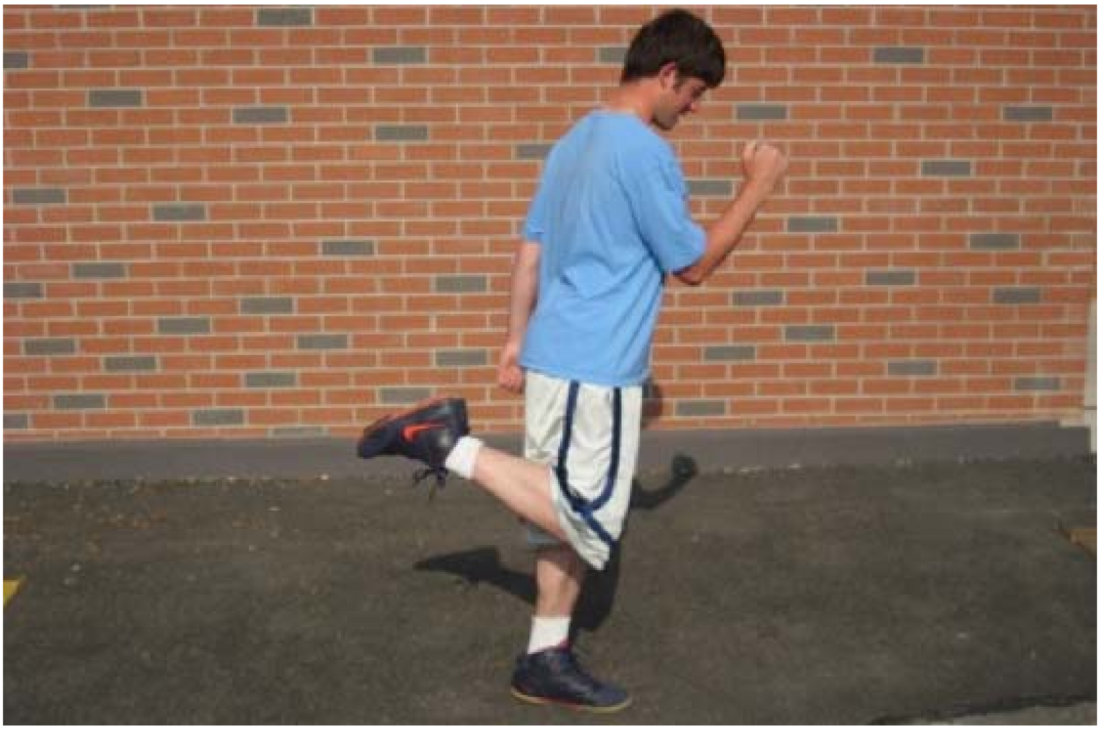
Teaching Points

Thigh to be taken past 90 degree angle
Work off the balls of the feet
Maintain a strong core
Maintain upright posture
Control head by looking forward at all times

Sets and Reps

1 x 20m forward
1 x 20m backwards

Hamstring Buttock Flick



Aim

To stretch front and back of thigh and improve mobility. To increase body temperature.

Description

Cover 20 metres by moving forwards alternating leg flicks, where the heel moves up towards the buttocks. Return to the start repeating the drill backwards.

Teaching Points

Start slowly and build up the tempo
Work off the balls of the feet
Do not sink into the hips
Maintain upright posture

Sets and Reps

1 x 20m forward
1 x 20m backwards

Walking Hamstrings

Aim

To stretch back of hip and thigh. To develop balance and co-ordination and increase body temperature.

Description

Cover 20 metres in bending at hips with one leg out in front. The leg in front is kept straight. Alternate legs when walking.

Teaching Points

Try and keep the hips square
Maintain a strong core
Maintain good control

Sets and Reps

1 x 20m forward
1 x 20m backwards

Forward Lunge

Aim

To improve front of hip and thigh stretch and develop core strength, balance and co-ordination. To increase body temperature.

Description

Cover 10 metres, performing a walking lunge. The front leg should be bent with a 90 degree angle at the knee and thigh in a horizontal position. The back leg should also be at a 90 degree angle with the knee almost touching the ground and thigh in a vertical position.

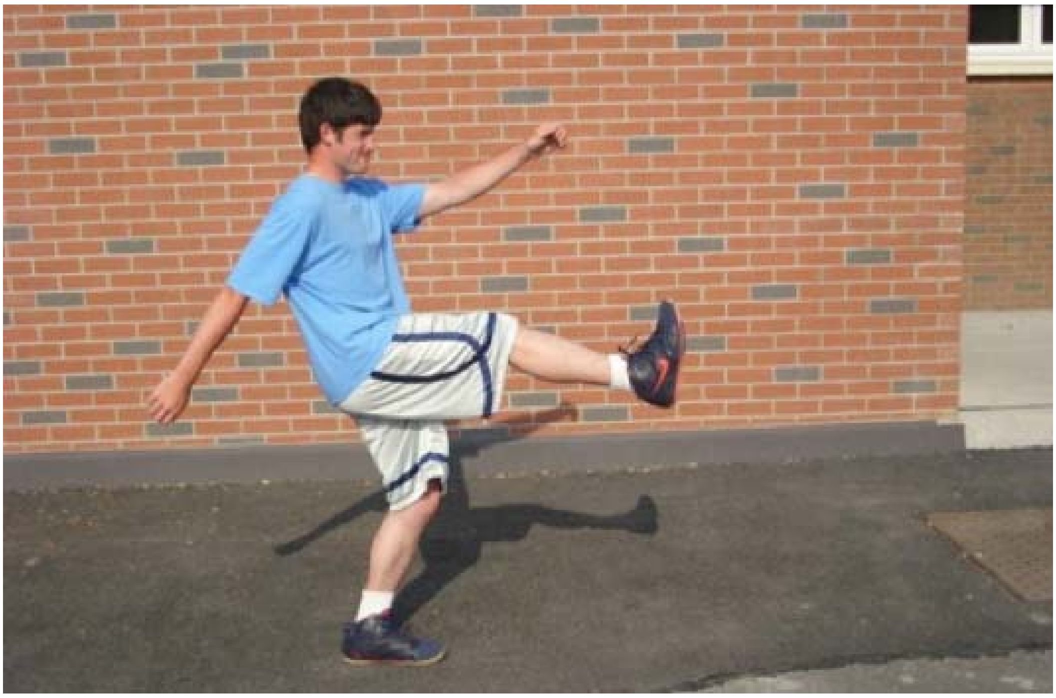
Teaching Points

Try to keep the hips square
Maintain good control
Maintain a strong core and keep upright
Look forward at all times

Sets and Reps

1 x 10m forward
1 x 10m backwards

Russian Walk



Aim

To stretch back of thigh and improve hip mobility and ankle stabilisation.

Description

Cover 20 metres by performing a walking march with a high, extended step.
Return to the start by repeating the drill backwards.

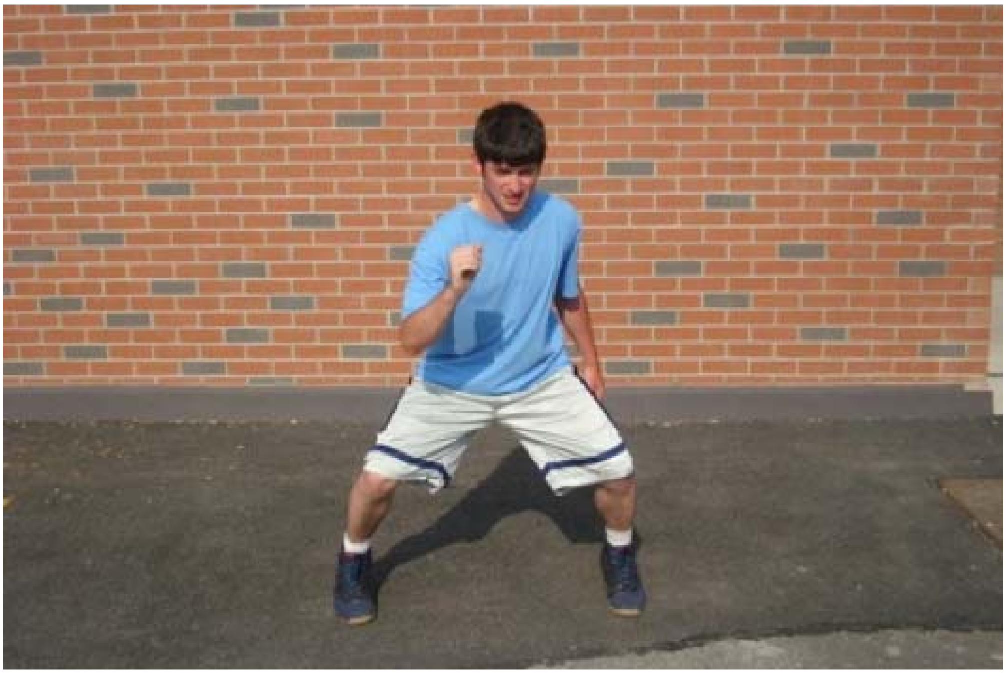
Teaching Points

Lift the knee before extending the leg
Work off the balls of the feet
Try to keep on the heels, particularly on the back foot
Keep the hips square

Sets and Reps

1 x 20m forward
1 x 20m backwards

Side Lunges



Aim

To stretch inner thigh and gluteal muscles. To develop balance and co-ordination. To increase body temperature.

Description

Cover 20 metres by performing lateral lunges. Take a wide sideways step and simultaneously lower the gluteals towards the ground. Return to the start with opposite shoulder leading.

Teaching Points

Do not bend at waist or lean forwards
Try to keep off the heels
Maintain a strong core and keeping upright

Sets and Reps

1 x 20m forward
1 x 20m backwards

Advanced Core Lunge

Aim

To improve front of hip and thigh stretch and develop core strength, balance and co-ordination. To increase body temperature.

Description

Cover 10 metres, performing a walking lunge with arm raises. The front leg should be bent with a 90 degree angle at the knee and thigh in a horizontal position. The back leg should also be at a 90 degree angle with the knee almost touching the ground and thigh in a vertical position. On the way down, the arms are pushed out and raised above the head as the back knee touches the ground.

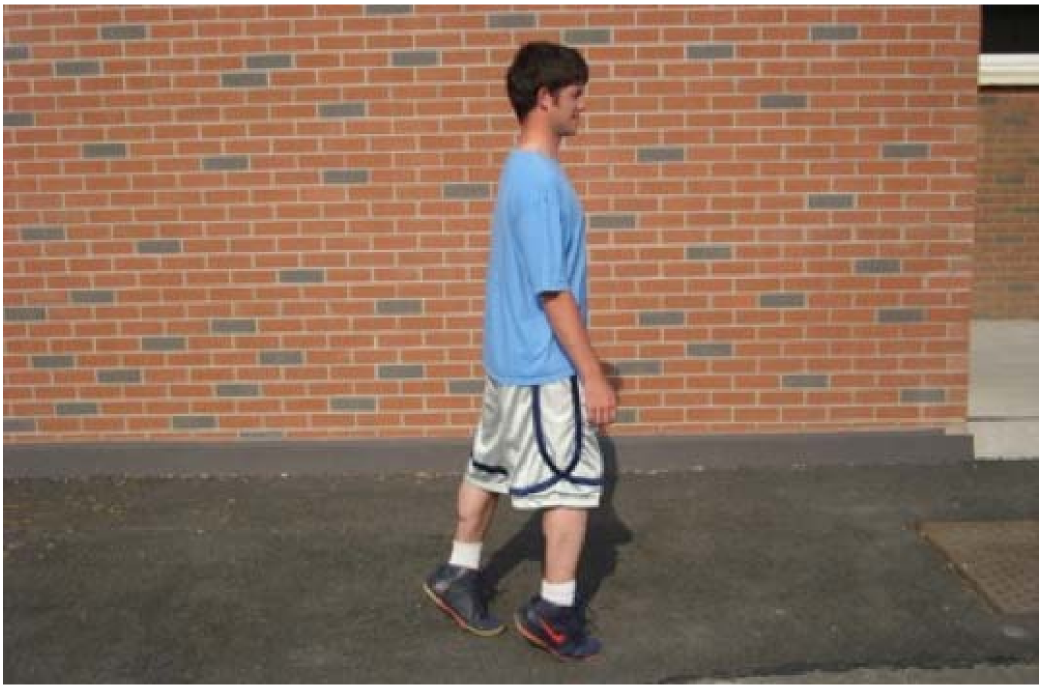
Teaching Points

Try to keep the hips square
Maintain good control
Maintain a strong core and keep upright
Look forward at all times

Sets and Reps

1 x 10m forward
1 x 10m backwards

Walking on the Balls of the Feet



Aim

To improve shin stretch, ankle mobility, balance and co-ordination. To increase body temperature.

Description

Cover 10 metres and back by walking on the balls of the feet.

Teaching Points

Do not walk on ends of the toes
Keep off the heels
Maintain an upright posture

Sets and Reps

2 x 30 metres forward

Wall Drill-Linear Leg Forward and Back

Aim

To increase the ROM in the hip region. To increase body temperature.

Description

Stand beside a wall, using the nearest arm to hold on to it for balance. Take the outer leg back and swing it forward in a straight line. Repeat with the other leg.

Teaching Points

Do not force an increase in ROM
Work off the ball of the support foot
Lean with both hands against the wall
Do not look down
Gradually speed up movement

Sets and Reps

1 x 10 left leg
1 x 10 right leg

Wall Drill-Leg Out and Across the Body

Aim

To increase the ROM in the hip region. To increase body temperature.

Description

Face and lean against a wall at about 20-30 degree angle. Swing the leg across the body from one side to the other. Repeat with the other leg.

Teaching Points

Do not force an increase in ROM
Work off the ball of the support foot
Lean with both hands against the wall
Do not look down
Gradually speed up movement
Keep hips square

Sets and Reps

1 x 10 left leg
1 x 10 right leg

Appendix 12 - Testing Sheet

Participants Name			
Test	Sit And Reach	20m sprint	Vetical Jump
Week 1			
Week 2			
Week 3			

Appendix 13 - Statistical Output

Statistical Output for 20 Metres

Descriptives

Control		*PNF*	
Mean	3.391666667	Mean	3.551944444
Standard Error	0.051735048	Standard Error	0.051991417
Median	3.381666667	Median	3.55
Mode	N/A	Mode	N/A
Standard Deviation	0.179215462	Standard Deviation	0.180103552
Sample Variance	0.032118182	Sample Variance	0.03243729
Kurtosis	-0.826221318	Kurtosis	2.007695343
Skewness	-0.32070887	Skewness	0.433654854
Range	0.56	Range	0.74
Minimum	3.06	Minimum	3.213333333
Maximum	3.62	Maximum	3.953333333
Sum	40.7	Sum	42.62333333
Count	12	Count	12
Largest(1)	3.62	Largest(1)	3.953333333
Smallest(1)	3.06	Smallest(1)	3.213333333
Confidence Level(95.0%)	0.113868072	Confidence Level(95.0%)	0.114432338

20 Metres Repeated Measures

Anova: Two-Factor Without Replication

SUMMARY	Count	Sum	Average	Variance
1	3	10.17	3.39	0.0036111
2	3	10.853333	3.6177778	0.0012926
3	3	10.94	3.6466667	0.0792444
4	3	10.146667	3.3822222	0.0270815
5	3	10.166667	3.3888889	0.0214481
6	3	10.256667	3.4188889	0.002737
7	3	10.08	3.36	0.0010111
9	3	9.3966667	3.1322222	0.005937
10	3	10.116667	3.3722222	0.0695259
11	3	10.813333	3.6044444	0.0017926
12	3	10.633333	3.5444444	0.0056259
13	3	10.476667	3.4922222	0.009437
Control	12	40.7	3.3916667	0.0321182
PNF	12	42.623333	3.5519444	0.0324373
Dynamic	12	40.726667	3.3938889	0.0211168

ANOVA

Source of Variatio	SS	df	MS	F	P-value	F crit
Rows	0.687608333	11	0.0625098	5.3975143	0.0003914	2.2585184
Columns	0.202701852	2	0.1013509	8.7513101	0.0015987	3.4433568
Error	0.254787037	22	0.0115812			
Total	1.145097222	35				

Paired T-test Control versus Dynamic

t-Test: Paired Two Sample for Means

	Control	Dynamic
Mean	3.3916667	3.3938889
Variance	0.0321182	0.0211168
Observatio	12	12
Pearson Co	0.7733927	
Hypothesiz	0	
df	11	
t Stat	-0.06764	
P(T<=t) one	0.4736428	
t Critical on	1.7958848	
P(T<=t) twc	0.9472857	
t Critical tw	2.2009852	

Paired T-test Control versus PNF

t-Test: Paired Two Sample for Means

	Control	PNF
Mean	3.3916667	3.5519444
Variance	0.0321182	0.0324373
Observatio	12	12
Pearson Co	0.5878502	
Hypothesiz	0	
df	11	
t Stat	-3.403816	
P(T<=t) one	0.0029446	
t Critical on	1.7958848	
P(T<=t) two	0.0058893	
t Critical tw	2.2009852	

Paired T-test PNF versus Dynamic

t-Test: Paired Two Sample for Means

	PNF	Dynamic
Mean	3.5519444	3.3938889
Variance	0.0324373	0.0211168
Observatio	12	12
Pearson Co	0.451359	
Hypothesiz	0	
df	11	
t Stat	3.1649008	
P(T<=t) one	0.0045	
t Critical on	1.7958848	
P(T<=t) two	0.009	
t Critical tw	2.2009852	

Statistical Output for Sit And Reach Test

Descriptives

Control		*PNF*	
Mean	26.25	Mean	27.58333333
Standard Error	2.05649378	Standard Error	1.900790638
Median	28	Median	29.5
Mode	30	Mode	30
Standard Deviation	7.123903424	Standard Deviation	6.58453192
Sample Variance	50.75	Sample Variance	43.35606061
Kurtosis	1.081130703	Kurtosis	0.945599837
Skewness	-0.891305536	Skewness	-0.91329108
Range	26	Range	24
Minimum	12	Minimum	14
Maximum	38	Maximum	38
Sum	315	Sum	331
Count	12	Count	12
Largest(1)	38	Largest(1)	38
Smallest(1)	12	Smallest(1)	14
Confidence Level(95.0%)	4.526312291	Confidence Level(95.0%)	4.183611987

Repeated Measures

Anova: Two-Factor Without Replication

SUMMARY	Count	Sum	Average	Variance
1	3	90	30	0
2	3	92	30.666667	1.3333333
3	3	70	23.333333	0.3333333
4	3	41	13.666667	2.3333333
5	3	48	16	3
6	3	86	28.666667	1.3333333
7	3	80	26.666667	0.3333333
9	3	89	29.666667	0.3333333
10	3	91	30.333333	2.3333333
11	3	84	28	1
12	3	114	38	0
13	3	86	28.666667	0.3333333
Control	12	315	26.25	50.75
PNF	12	331	27.583333	43.356061
Dynamic	12	325	27.083333	38.265152

ANOVA

rce of Varia	SS	df	MS	F	P-value	F crit
Rows	1441.6389	11	131.05808	199.61154	2.183E-19	2.2585184
Columns	10.888889	2	5.4444444	8.2923077	0.0020706	3.4433568
Error	14.444444	22	0.6565657			
Total	1466.9722	35				

Paired T-test Control versus Dynamic

t-Test: Paired Two Sample for Means

	Control	Dynamic
Mean	26.25	27.083333
Variance	50.75	38.265152
Observations	12	12
Pearson Correlation	0.9917606	
Hypothesized Mean Difference	0	
df	11	
t Stat	-2.277867	
P(T<=t) one-tail	0.0218498	
t Critical one-tail	1.7958848	
P(T<=t) two-tail	0.0436996	
t Critical two-tail	2.2009852	

Paired T-test Control versus PNF

t-Test: Paired Two Sample for Means

	Control	PNF
Mean	26.25	27.583333
Variance	50.75	43.356061
Observations	12	12
Pearson Correlation	0.994702804	
Hypothesized Mean Difference	0	
df	11	
t Stat	-5.20354908	
P(T<=t) one-tail	0.000146433	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	0.000292865	
t Critical two-tail	2.20098516	

Paired T-test PNF versus Dynamic

t-Test: Paired Two Sample for Means

	PNF	Dynamic
Mean	27.583333	27.083333
Variance	43.356061	38.265152
Observatioi	12	12
Pearson Co	0.9829794	
Hypothesiz	0	
df	11	
t Stat	1.3932611	
P(T<=t) one	0.0955271	
t Critical on	1.7958848	
P(T<=t) twc	0.1910543	
t Critical tw	2.2009852	

Statistical Output for Vertical Jump

Descriptive

Control		*PNF*		*Dynamic*	
Mean	17.67222222	Mean	17.56388889	Mean	18.09444444
Standard Error	0.374589188	Standard Error	0.401312207	Standard Error	0.404578871
Median	17.5	Median	17.5	Median	17.5
Mode	N/A	Mode	N/A	Mode	19.8
Standard Devia	1.29761501	Standard Devia	1.390186263	Standard Devia	1.40150232
Sample Varianc	1.683804714	Sample Varianc	1.932617845	Sample Varianc	1.964208754
Kurtosis	-1.277224923	Kurtosis	-0.698779215	Kurtosis	-1.759859438
Skewness	0.401418374	Skewness	0.275566653	Skewness	0.34191558
Range	3.733333333	Range	4.533333333	Range	3.733333333
Minimum	16.2	Minimum	15.33333333	Minimum	16.3
Maximum	19.93333333	Maximum	19.86666667	Maximum	20.03333333
Sum	212.0666667	Sum	210.7666667	Sum	217.1333333
Count	12	Count	12	Count	12
Largest(1)	19.93333333	Largest(1)	19.86666667	Largest(1)	20.03333333
Smallest(1)	16.2	Smallest(1)	15.33333333	Smallest(1)	16.3
Confidence Lev	0.824465243	Confidence Lev	0.883282211	Confidence Lev	0.890472091

Repeated Measures

Anova: Two-Factor Without Replication

SUMMARY	Count	Sum	Average	Variance
1	3	49.366667	16.455556	0.077037
2	3	51.2	17.066667	0.07
3	3	56.033333	18.677778	0.9514815
4	3	57.466667	19.155556	0.2237037
5	3	54.566667	18.188889	0.2603704
6	3	50.7	16.9	0.1077778
7	3	48.966667	16.322222	0.0003704
9	3	59.6	19.866667	0.0044444
10	3	58.766667	19.588889	0.2192593
11	3	48.7	16.233333	0.8411111
12	3	54.1	18.033333	0.27
13	3	50.5	16.833333	0.1011111
Control	12	212.06667	17.672222	1.6838047
PNF	12	210.76667	17.563889	1.9326178
Dynamic	12	217.13333	18.094444	1.9642088

ANOVA

rce of Varia	SS	df	MS	F	P-value	F crit
Rows	57.019599	11	5.1835999	26.111786	4.335E-10	2.2585184
Columns	1.8859877	2	0.9429938	4.7502226	0.0192826	3.4433568
Error	4.3673457	22	0.1985157			
Total	63.272932	35				

Paired T-test Control versus Dynamic

t-Test: Paired Two Sample for Means

	Control	Dynamic
Mean	17.67222222	18.09444444
Variance	1.683804714	1.964208754
Observations	12	12
Pearson Correlati	0.855650136	
Hypothesized Me	0	
df	11	
t Stat	-1.998113978	
P(T<=t) one-tail	0.035516546	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	0.071033091	
t Critical two-tail	2.20098516	

Paired T-test Control versus PNF

t-Test: Paired Two Sample for Means

	Control	*PNF*
Mean	17.672222	17.563889
Variance	1.6838047	1.9326178
Observatioı	12	12
Pearson Co	0.9445258	
Hypothesiz	0	
df	11	
t Stat	0.8214458	
P(T<=t) one	0.2144186	
t Critical on	1.7958848	
P(T<=t) twc	0.4288371	
t Critical tw	2.2009852	

Paired T-test PNF versus Dynamic

t-Test: Paired Two Sample for Means

	PNF	*Dynamic*
Mean	17.563889	18.094444
Variance	1.9326178	1.9642088
Observations	12	12
Pearson Correlation	0.885434	
Hypothesized Mean Difference	0	
df	11	
t Stat	-2.750318	
P(T<=t) one-tail	0.00944	
t Critical one-tail	1.7958848	
P(T<=t) two-tail	0.0188799	
t Critical two-tail	2.2009852	